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HIGH-RIGIDITY SLIDING MATERIAL  
[Kogosei Setsudo Zairyo]

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## Specification

1. Title of the invention

High-Rigidity Sliding Material

2. Claim

A high-rigidity sliding material, characterized by the fact that titania fibers are mixed in a synthetic resin.

3. Detailed explanation of the invention

(Industrial application field)

The present invention pertains to a high-rigidity sliding material that requires both characteristics of a high rigidity and sliding characteristics.

(Prior art)

As high-rigidity sliding materials that require a high rigidity and a low friction characteristic during sliding, for example, gears and bearings themselves or housing for integrating bearings, etc., fiber-reinforced composite materials in which various kinds of reinforcing fibers are mixed with a synthetic resin as a matrix are broadly used.

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<sup>1</sup> Numbers in the margin indicate pagination in the foreign text.

Then, as one of reinforcing materials for these composite materials, potassium hexatitanate fibers and glass fibers are known.

However, in the conventional fiber-reinforced composite materials that have been used as high-rigidity sliding materials, there are the following problems, and it is difficult to say that the composite materials up to now always have optimum characteristics as high-rigidity sliding materials in actuality.

In other words, for example, in a composite material in which potassium hexatitanate fibers are mixed as a reinforcing material, if the other party material during sliding is a hard metal material such as iron and steel products and Al product, the coefficient of kinetic friction is high, and the amount being worn is increased in both the hard metal material and the other party. Also, in a composite material in which glass fibers are mixed as a reinforcing material, the coefficient of kinetic friction is higher than that of the above-mentioned composite material, although its amount being worn is decreased, so that the other party material is worn out much. Furthermore, in a composite material in which the above-mentioned potassium hexatitanate fibers are mixed, the sliding characteristics are more inferior to those of the

above-mentioned glass fiber-reinforced composite material in accordance with the kind of synthetic resin being a matrix.

(Problems to be solved by the invention)

The present invention solves these technical problems, and its purpose is to provide a high-rigidity sliding material in which the coefficient of kinetic friction is low and the amount being worn can be reduced as much as possible in both the sliding material and the other /2 party being.

(Means to solve the problems)

In order to achieve the above-mentioned purpose, the essence of the high-rigidity sliding material of the present invention is characterized by the fact that titania fibers are mixed in a synthetic resin.

(Operation)

These inventors since the characteristics of the fiber-reinforced composite materials depend on the characteristics of the reinforcing fibers, the characteristics of the conventional reinforcing materials reviewed. As a result, in case potassium hexatitanate fibers are used as the reinforcing material, since the mohs hardness of said fibers is as relatively low as 4, when the other party material has a hard hardness like a metal

material, it is simply worn out, and a large amount of worn powder is generated, though they are fine powders, so that a rough worn-out state is formed. Thereby, the amount being worn in the other party is also increased. Also, in case glass fibers are used as the reinforcing material, the mohs hardness of said fibers is as relatively high as 6, and the glass fibers themselves are difficult to be worn out, however since the fiber diameter is thick, relatively large worn-out powders are generated, and when sliding, a rough worn-out state in which an abrasive is sandwiched is formed.

Accordingly, these inventors considered that if fibers with appropriate hardness and diameter were mixed as a reinforcing material, a desired fiber-reinforced composite material could be obtained and repeated various reviews. As a result, it was discovered that titania fibers (titanium oxide fibers) were reinforcing materials that met the above-mentioned requirements. In other words, in a fiber-reinforced composite material in which the titania fibers are used as a reinforcing material, when it is used as a sliding material, the coefficient of kinetic friction is decreased, so that the amount being worn is reduced in the composite material and the other party material and the temperature rise due to the frictional heat is also

decreased. In other words, since the diameter of the titania fibers is about the same as that of the above-mentioned potassium titanate fibers and their mohs hardness is 5, the powders being worn out are reduced, and the amount being worn out is also reduced, so that the sliding resistance (coefficient of kinetic friction) is decreased. In addition, since the elastic modulus of the titania fibers is twice of the above-mentioned potassium hexatitanate and 8 times of the glass fibers, the fiber-reinforced composite material exhibits a high rigidity when the titanate fibers are used as a reinforcing material. Furthermore, since the titania fibers have a fine fiber diameter that is about the same as that of the potassium titanate fibers, the dispersibility into the matrix is improved, so that the anisotropy in the properties of the composite material being obtained is reduced, the warp is little, and the surface is smooth.

Also, the titania fibers being used in the present invention is obtained heating and dehydrating hydrated titanatic acid fibers at several hundreds °C or higher and can also be easily obtained by oxidizing with an air in a chloride molten salt containing titanium tetrachloride. Also, it has already been known that the hydrated titanatic acid fibers are obtained by a method that hydrothermally

acicular alkali titanate (generally, potassium tetratitanate fibers being obtained by a baking method or flux method) with water or an acid solution and removes the alkali (Yanagida and Shimizu, Journal of Fiber Society, 34 (1978), 319), a method that treats a plate-shaped alkali titanate (generally, potassium dititanate fibers obtained by a melt method) with an acid aqueous solution and removes the alkali (Fujiki and Osaka, Journal of Ceramic Association, 90 (1982), 19), or a method that oxidizes an aqueous titanium trichloride solution with an air (Powder Metallurgy Association, 1980 Fall Convention Lecture Summary 2-6, p.86).

Since the mixture ratio of the titanate fibers depends on the kind of synthetic resin being a matrix, it is not limited at all, however the ratio is preferably about 5-50 wt%. Furthermore, the kind of synthetic resin being used as a matrix is not limited at all, and for example, thermoplastic resins such as polyamide resin, polyacetal resin, polycarbonate resin, polybutylene terephthalate resin, polyphenylene sulfide resin, polyethylene terephthalate resin, polypropylene resin, ABS resin, polyether ether ketone resin, and polyether sulfone resin or thermosetting resins such as phenol resin, epoxy resin,



unsaturated polyester resin, and urethane resin are mentioned.

Also, with the use of a sliding enhancer (fluororesin powder, silicone, silicon powder, polyethylene, mineral oil, molybdenum disulfide, etc.) in combination is preferable in further improving the sliding characteristics of the sliding material of the present invention.

Next, the present invention is explained in further detail by application examples, however the following /3 application examples do not limit the present invention. Any design change through the above-mentioned essence is included in the technical range of the present invention. (Application examples)

Next, titania fibers were manufactured by the following process.

(I) Preparation of raw materials

(1) Titanium compound: natural rutile sand (produced in Australia)

<Component> (wt%)

TiO<sub>2</sub>: 95.6%, Fe<sub>2</sub>O<sub>3</sub>: 0.6%, P: 0.01%, S: 0.02%, ZrO<sub>2</sub>: 0.7%, Cr<sub>2</sub>O<sub>3</sub>: 0.3%, SiO<sub>2</sub>: 0.6%, V<sub>2</sub>O<sub>5</sub>: 0.7%, Nb<sub>2</sub>O<sub>3</sub>: 0.3%, Al<sub>2</sub>O<sub>3</sub>: 0.4%, MnO: 0.01%, CaO: 0.03%, MgO: 0.03%, and the balance: an infinitesimal amount of Co, Ca, etc.

(2) Potassium compound: K<sub>2</sub>CO<sub>3</sub> (purity: 99.5%)

(3)  $\text{TiO}_2/\text{K}_2\text{O}$  (mol ratio): 2.0

(II) Heating melting

A raw material mixed powder was put into a platinum crucible and heated at  $1,100^\circ\text{C}$  for 40 min.

(III) Rapid cooling treatment

The melted product was flown down to a metal twin roll being rotated at high speed, so that a solidified product with a foil segment shape was obtained.

It was confirmed from an X-ray diffraction that the solidified product was amorphous.

(IV) Baking treatment

The above-mentioned natural rutile sand was mixed with the above-mentioned amorphous solidified product at a mol ratio of  $\text{TiO}_2/\text{K}_2\text{O}$  of 3.0 and pulverized by a disk mill, so that a uniform powder mixture (average particle size:  $5\ \mu\text{m}$ ) was attained. Next, the powder mixture was charged into an aluminum crucible, heated at  $1,000^\circ\text{C}$  for 0.5 h and held.

The above-mentioned baked product was charged into water at an amount of 10 times (weight ratio), and the fibers were shredded for 15 min by a mixer, dehydrated, and dried, so that potassium tetratitanate fibers were obtained. Its diameter was  $0.2\text{--}1\ \mu\text{m}$ , and its length was  $5\text{--}20\ \mu\text{m}$ .

#### (V) Potassium removal treatment

The potassium tetratitanate fibers obtained in this manner was immersed into an aqueous sulfuric acid solution (5 %) as a washing solution (1 g fibers/10 cc washing solution), and  $K^+$  ions were eluted for about 60 min. Then, the fibers were washed with water and dried.

#### (IV) Baking treatment

The fibers from which the potassium was removed was put into an aluminum crucible, charged into a furnace set at 400°C, and baked for about 0.5 h.

As a result of its X-ray analysis, it was shown that the fibers obtained were titania fibers (anatase phase). Also, the fiber shape was 0.1-1  $\mu m$  in diameter and 5-20  $\mu m$  in length.

As a matrix, nylon 66 (Ny66), polybutylene terephthalate (PBT), polyacetal (POM), polyphenylene sulfide (PPS), or a resin in which polyethylene (PE) is mixed with Ny66 were used, and the above-mentioned titania fibers (application example) and the potassium hexatitanate or glass fibers (comparative example) were mixed with the above-mentioned matrix at ratios shown in the following Table 1, so that various kinds of fiber-reinforced composite materials were manufactured. For each composite material obtained, the specific gravity, the tensile

strength, and the bending elastic modulus were respectively measured according to ASTM D792, ASTM D638, and ASTM D790, and the sliding performances were investigated by a Suzuki type wear test (stress  $P = 10 \text{ kgf/cm}^2$ , speed  $V = 30 \text{ cm/sec}$ ). Also, for the sliding performances, a S45C stainless steel with a surface roughness (Ra) of 0.50 was used as the other party material, and after rotating and sliding said other party material for 1 h, the value was attained.

The results are also shown in Table 1, and for the specific gravity, the tensile strength, and the bending elastic modulus in Table 1, the absolute values of the mixture with Ny66 as a matrix are shown.

Table 1

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No.	配合割合 (重量%)	比重	引張り 強さ ( $\text{kgf/cm}^2$ )	曲げ弾性 係数 ( $\text{kgf/cm}^2$ )	耐磨特性				備考
					嵌合係数	比摩耗量 ( $\text{cm}^3/\text{kgf}\cdot\text{h}$ )	相手材比摩耗量 ( $\text{cm}^3/\text{kgf}\cdot\text{h}$ )	磨動面温度 ( $^{\circ}\text{C}$ )	
1	Ny66:70, チタニア繊維:30	1.41	1400	11000	0.36	0.34	0.007	56	実施例
2	Ny66:70, 5-チタン酸カリウム繊維:30	1.42	1320	9500	0.40	0.55	0.006	75	比較例
3	Ny66:70, ガラス繊維:30	1.50	1750	8300	0.60	0.38	0.010	90	"
4	PBT:70, チタニア繊維:30	1.53	1080	10500	0.25	0.15	0.031	52	実施例
5	PBT:70, 5-チタン酸カリウム繊維:30	1.61	1030	9300	0.39	0.23	0.001	73	比較例
6	PBT:70, ガラス繊維:30	1.52	1320	9000	0.56	0.18	0.012	85	"
7	POM:80, チタニア繊維:20	1.58	880	7500	0.30	0.42	0.007	80	実施例
8	POM:80, 5-チタン酸カリウム繊維:20	1.59	810	6700	0.43	0.65	0.003	80	比較例
9	POM:80, ガラス繊維:20	1.54	900	6500	0.70	1.02	0.015	102	"
10	PPS:60, チタニア繊維:40	1.78	1380	13100	0.24	0.48	0.001	50	実施例
11	PPS:60, 5-チタン酸カリウム繊維:40	1.79	1350	14000	0.37	0.83	0.002	72	比較例
12	PPS:60, ガラス繊維:40	1.66	1720	12500	0.50	0.05	0.017	90	"
13	Ny66:63, PE:7, チタニア繊維:30	1.38	1270	9500	0.11	0.35	0.001	42	実施例
14	Ny66:63, PE:7, 5-チタン酸カリウム繊維:30	1.39	1250	8000	0.16	0.08	0.002	47	比較例
15	Ny66:63, PE:7, ガラス繊維:30	1.34	1580	7500	0.28	0.07	0.002	56	"

reinforcing material while commonly using the matrix, the composite materials in which the titania fiber is mixed have a rigidity higher than that of the composite materials in which the potassium hexatitanate or glass fibers are mixed.

(Effects of the invention)

As mentioned above, according to the present invention, with the formation of the composite material by using titania fibers as a reinforcing material, a high-rigidity sliding material in which the coefficient of kinetic friction is low and the amount of wear is reduced as much as possible in the sliding material and the other party material can be realized.